How Hydrogeology Affects the Efficiency of Natural Attenuation

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U.S. Geological Survey

OSWER recognizes that Natural Attenuation Processes include physical, biological, and chemical processes . These are:

- Physical (Dispersion, advection).
- Chemical transformations (sorption).
- Biological processes (reduction, oxidation).

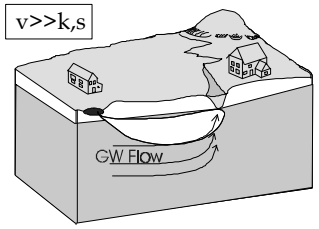
How can we take all of these processes into account?

- To illustrate, let s do a mental experiment.

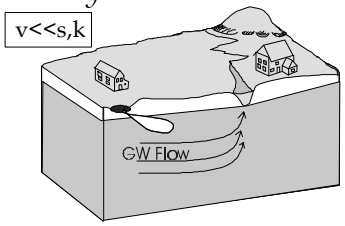
Consider a contaminant spill that reaches the water table. The size of the contaminant plume that develops is controlled by:

- Size of the spill.
- velocity of G.W. flow (v).
- Sorptive capacity of aquifer solids (s).
- Biodegradation (k).

If v is large compared to s and k, the plume will be relatively large.



Conversely, if v is small relative to s and k, the plume will be relatively small.



<u>Postulate</u>: The efficiency of natural attenuation is inversely proportional to the distance of contaminant migration

$$E \sim 1/d$$

<u>Therefore</u>: The efficiency of natural attenuation depends on:

- Velocity of ground water
- Sorptive capacity of aquifer
- Rates of biodegradation

This reasoning is useful because it can be quantified:

$$\frac{\partial C}{\partial t} = \underbrace{D\frac{\partial^2 C}{\partial x^2}}_{\text{dispersion}} - \underbrace{v\frac{\partial C}{\partial x}}_{\text{advection}} - \underbrace{\underbrace{SC^n}_{\text{sorption}} - \underbrace{kC}_{\text{biodegradation}}}_{} \quad (1)$$

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This is saying mathematically, what the OSWER Directive says in English.

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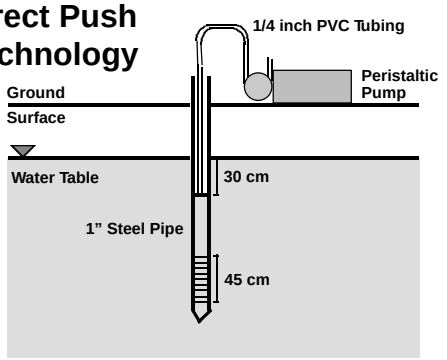
The key to assessing natural attenuation is to have:

- Hydrologic information (directions and rates of GW flow).
- Geochemical information (sorptive capacity of aquifer sediments).
- Microbiologic information (rates of biodegradation).

How do you get this information?

- Hydrologic testing (hydraulic conductivity, water-level maps)
- Geochemical testing (redox conditions, sorptive capacity).
- Microbiologic testing (field and/or lab).

Direct Push Technology

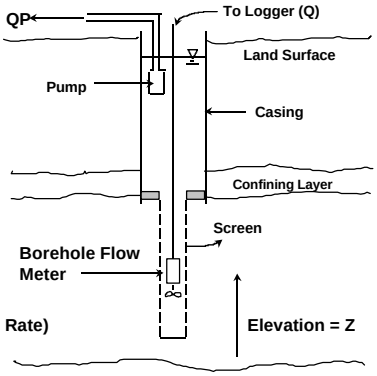


Application of the Electromagnetic Borehole Flowmeter

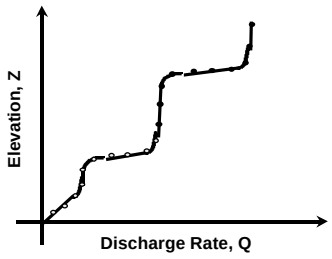
Steven C. Young, Hank E. Julian, Hubert S. Pearson, Fred J. Molz, and Gerald K. Boman

EPA/600/SR-98/058

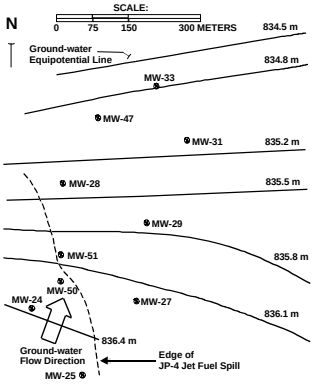
Apparatus and Geometry Associated with a Borehole Flowmeter Test



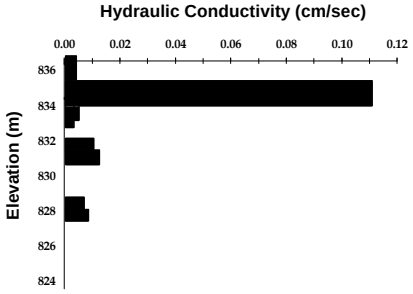
Data from a Borehole Flowmeter Test



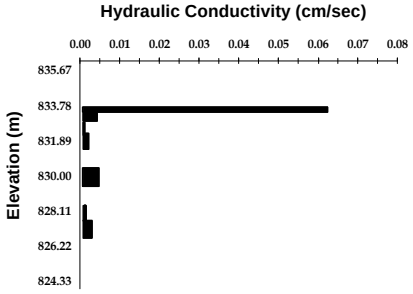
George Air Force Base, California



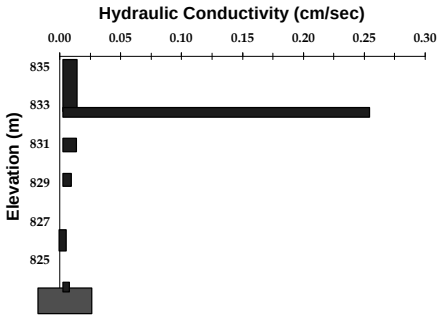
Hydraulic Conductivity - MW 27



Hydraulic Conductivity - MW 29



Hydraulic Conductivity - MW 31



George AFB

Monitoring Well	Average Hydraulic Conductivity (cm/sec)	Hydraulic Conductivity of Most Transmissive Interval (cm/sec)
MW-27	0.0074	0.11
MW-28	0.0046	0.022
MW-29	0.0028	0.062
MW-31	0.013	0.26
MW-45	0.0032	0.0056
MW-46	0.018	0.40

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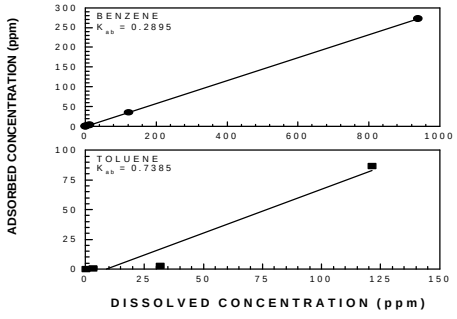

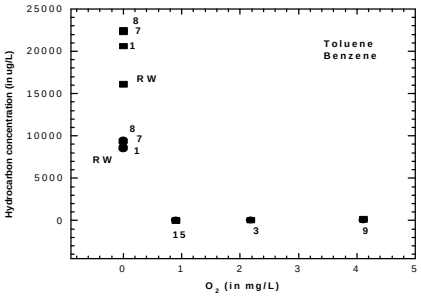

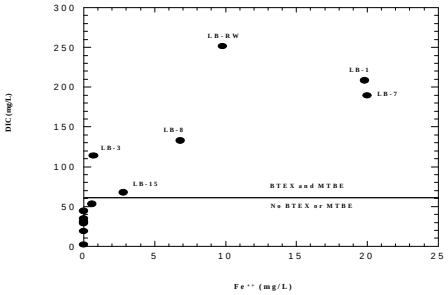

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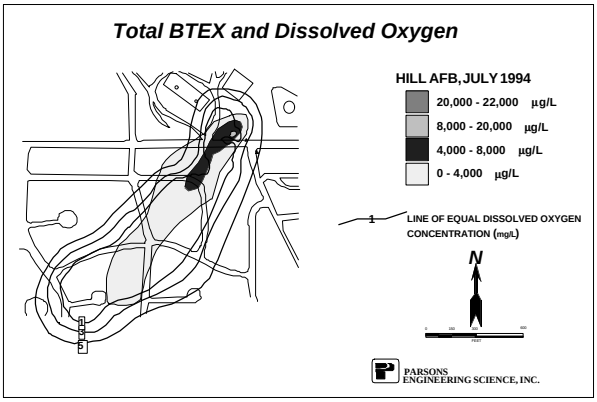

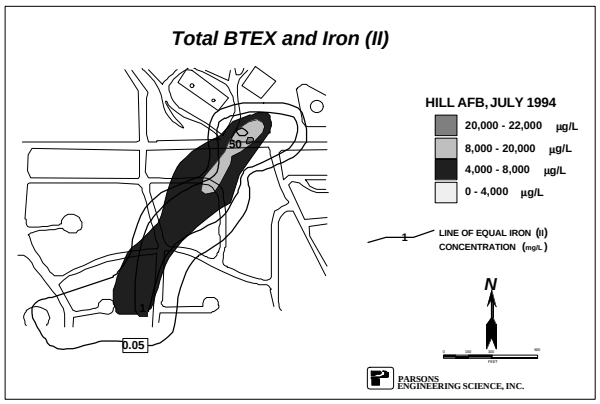

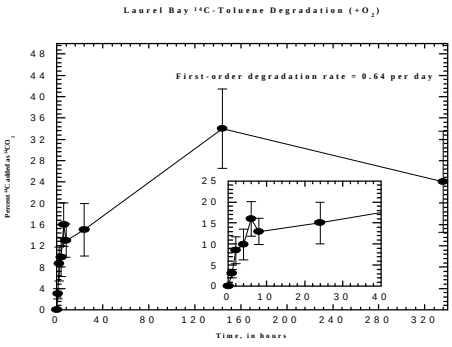

Analytic or Digital Soulutions can then be used to assess Natural Attenuation:

$$\frac{\partial C}{\partial t} = \underbrace{D\frac{\partial^2 C}{\partial x^2}}_{\text{dispersion}} - \underbrace{v\frac{\partial C}{\partial x}}_{\text{advection}} - \underbrace{SC^n}_{\text{sorption}} - \underbrace{kC}_{\text{biodegradation}} \quad (1)$$

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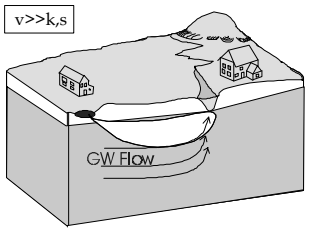

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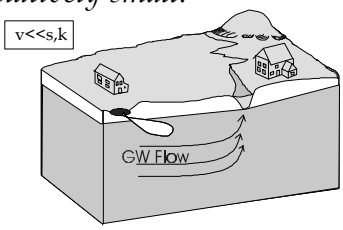
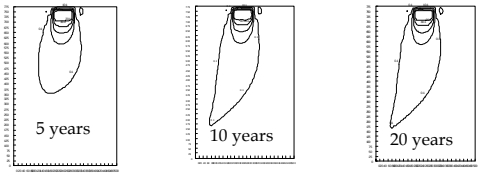


Example 1: Source Remains in Place:Plume becomes stable.



Example 2: Source Removed: Plume dissipates.

Even with sophisticated models, there is still uncertainty!

- Predictive models must be tested against historical data.
- Modeling must be verified with monitoring data.